BOWMAN

History and development of the steel industry

Civil Engineering

B. S.

1910

HISTORY AND DEVELOPMENT OF THE STEEL INDUSTRY

BY

HORACE DALE BOWMAN

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1910

UNIVERSITY OF ILLINOIS

COLLEGE OF ENGINEERING.

June 1, 1910

This is to certify that the thesis of HORACE DALE BOWMAN entitled History and Development of the Steel Industry is approved by me as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

C.W. Malcolm

Instructor in Charge.

Approved:

Professor of Civil Engineering.

TABLE OF CONTENTS.

History and Development of the Steel Industry.

A century ago when wood, stone, and brick were the chief materials of construction, the engineer, as we know him today, was unknown. There was little need of the engineering profession in those days, for all buildings, bridges, ships, etc., were built according to custom. The materials used were at that time so plentiful and cheap that any effort made to investigate and determine a more economical way of using them usually proved extravagant.

The advent of iron and steel into general use caused a new condition. The adaptability of both these materials to many uses, and their evident superiority in strength, durability, and ease of shaping and handling, proved to the ancients their decided advantage over all previously used constructive materials.

The use of iron and steel was long delayed by the lack of scientific knowledge. The early processes of smelting and refining the resulting product were both inefficient and expensive, giving a non-uniform grade of metal at a high cost. These conditions caused the beginning of a long series of investigations and experiments which constitute the history and development of the steel industry.

The complexity of the problems that confronted early investigators and the necessity for an economical use of the finished product, proved the need of men especially trained and experienced in those lines. This necessity probably has been the greatest cause for the development of the engineering

professions. Further discoveries and inventions have called for specialized professional knowledge, until now we find engineering divided into a number of different branches. While it may seem a trifle far-fetched to claim that all of these recently developed branches of engineering are the direct result of a new field of use for steel, the importance of the relation between this metal and the engineering profession can be seen by trying to realize the possibility of the existence of such a profession without the use of iron and steel.

General History of the Steel Industry.

Historians have found it impossible to determine the beginning of the use of iron and steel, for its initial appearance occurred when history was dependent on myth and legend. The earliest ages of historical antiquity give evidence of the use of iron. In the Old Testament are mentioned men, who as early as the fourth generation after Adam made a specialty of being "forgers of every cutting instrument of brass and iron".

The earliest known use of iron was in Western Asia and Northern Africa. Relics have been found and history positively proves the use of iron and steel for tools and weapons by the Egyptians, Carthaginians, Libyans, Chaldeans, Babylonians, Assyrians, and Romans.

The Persians, the Medes, the Parthians, and other Scythian tribes made iron and steel long before the Christian era. The only use they found for steel, however, was for weapons, and their processes were so expensive that they used it only to tip arrowheads and rim shields. China, India, Japan, and Korea claim to have manufactured iron and steel as early as 2000 B.C.; but we have little proof of this as their ancient histories

consist merely of family traditions, and no relics of that early date appear to have survived.

The authentic history of iron begins in Greece about 700 B.C. and by the time that Rome was built, 753 B.C., there was an established art of metallurgy, which was imparted to the Romans by the Greeks. At the beginning of the Christian era, iron and steel were being used for impliments of agriculture, weapons, tools, and also for architectural purposes. In the Acts of the Apostles is a statement indicating that city gates were then made of iron.

Shortly after this, the Phoenicians in Spain became expert in the manufacture of steel and its tempering. After the conquest of Spain by the Romans, the manufacture of steel swords in Toledo became an enormous industry. We still know the famous quality of the Toledo blade even though it has passed its period of usefulness as a weapon.

Very little is known of the development of the iron and steel industries for several centuries after Caesar's time. History speaks of "skilled workers of iron and steel" accompanying William the Norman when he invaded England in 1066. The blast furnace is supposed to have been first used at the beginning of the fourteenth century, but it is not known whether it originated in France, Germany, or Belgium. By 1450, many blast furnaces were in use in each of these three countries.

The cause of England's iron and steel manufacture developing into an enormous industry was her tendency toward commercialism. An extensive use of both metals was limited by the

expense of the early processes of production. By the beginning of the fifteenth century England was exporting cannon and other products of iron and steel. At this time the introduction of the blast furnace in England gave the industry an added impetus, for prior to this, only wrought iron and steel had been produced.

During the fifteenth and sixteenth centuries the development of this industry was marvelous. England was possessed of natural resources that soon made her the foremost of all nations as a producer of iron and steel. By 1483, the English manufactures were so well established that an act was passed prohibiting the importation of all iron and steel products excepting those made of the finest steels. Sussex was the seat of the English iron industry. An ancient chronicler has stated that every person, except the nobility, was in some way engaged in or connected with the manufacture of iron or steel.

However, England was not destined to retain for any length of time her lead in iron production. A new and alarming condition now compelled England to give up her supremacy in the industry. Up to this time charcoal was the only fuel that had proved practical for refining iron. The magnitude of the industry in England had made great inroads in the timber supply and England was now threatened with a timber famine unless stringent measures were taken. In 1558 an act was passed prohibiting the cutting of timber for use in iron manufacture. Later, additional acts were passed until the iron industry in Kent, Sussex, and Surrey became extinct.

During the middle of the seventeenth century all manufactures in England were seriously checked by the Cromwellian

Rebellion. This, together with the scarcity of timber, combined to check the iron and steel industry, until at the beginning of the eighteenth century England was not manufacturing enough for the local market. Throughout the seventeenth and eighteenth centuries much iron was imported from Sweeden, Russia, and America.

England was compelled to import the most of her iron and steel until the middle of the eighteenth century when mineral fuel in the form of coke came into use. The iron trade of the country rapidly revived. This revival of the iron and steel industry in England was followed by an era of improvement of the methods of its manufacture and handling. In 1783 Henry Cort patented a method of making iron bars by grooved iron rolls; and this, together with other improvements, placed Great Britain again foremost in the steel trade.

While England was engaged and engrossed in her principal industry, the United States had been far from idle in this line. In no other part of America had the manufacture of iron and steel become a national industry. It is a well established fact that the aborigines of America knew nothing of iron except that which was of meteoric origin. It was not until during the latter part of the seventeenth century that manufacture of iron and steel in the colonies showed indications of becoming an important industry. Up to the time of the Revolution it experienced a steady growth until at that time it held first rank in commercial importance among all American productive and manufacturing industries. Before this time the American manufactures had been greatly hindered by the

unfriendly legislation of Great Britain. It was her object to suppress all American industries except those which furnished raw materials suitable for further manufacture in England.

The Declaration of Independence gave to the United States both political and industrial freedom, and consequently the iron and steel industry was soon in the course of the development it deserved as America's greatest commercial resource. Furnaces, smelters, foundries, and factories were built in nearly every state of the Union. Developments and improvements in the processes used increased the quality and cheapness of the finished products, until today the United States is both the largest producer and the largest per capita consumer of steel in the world.

However, the United States did not gain this first rank in steel production without a long and bitter struggle. Between the Revolution and the early part of the nineteenth century nearly all American manufacturing interests were checked by the lack of a protective tariff. Well established and experienced foreign industries could market their finished products in America at a cost below that of their local competitors. Congress did not remove this obstruction entirely until 1812 when public opinion made it evident that the need of protection for American infant industries was imperative.

The lack of protection was not the only obstruction to the industrial progress of steel. Wages in the iron and steel industries of the United States were much higher than those of the European competitors. In most cases the raw material had to be transported greater distances, hence this expense was much larger. To offset these disadvantages, American

inventive genius has labored for a century to perfect and systematize the old, and to furnish new methods for producing the best steel at the lowest cost. Their success is evidenced by the present ranking of the United States in the steel industry.

History and development of the processes of manufacture.

During the many centuries since the ancients discovered iron, the increase in its manufacture and use has been greatly retarded by the slow development of the processes used. Until quite recently the demand has constantly exceeded the supply; and since the amounts of raw materials- such as ore and fuel- are practically unlimited, the processes alone are largely responsible for the long period of time it has taken to build up the steel industry.

The methods of manufacturing iron, which were used in the earliest ages, were very few in number and extremely simple. The primitive method consisted simply in the use of the modern blast-furnace in elementary form. The equipment consisted of a furnace which was usually partly excavation and from six to twelve feet in height. In most cases this furnace was provided with means for furnishing artificial draft. However, some furnaces were so constructed that the prevailing winds could be utilized to give a natural draft. Where artificial blast was required, it was usually furnished by goat-skin bellows, except in India, China, Japan, Madagascar, and Borneo, where blowing cylinders made of bamboo were used. The principle of the blowing cylinder is the same as that of the modern lift pump, as it consists of a valved piston working in a hollow tube.

These early forms of furnaces were charged with ore,

usually hematite, and either charcoal or wood was used for fuel. After burning, the resulting product was a lump of low- grade malleable iron, which was removed and later was cut and forged into the desired shapes. The draft, or blast, used in these early methods was very mild so the process greatly resembled that of the open-hearth.

The far-famed Indian steel, or wootz, is manufactured to-day in practically the same manner that it was two thousand years ago. It is the earliest authentic method of steel manufacture of which we have any description, as it was described by Aristotle several centuries before the beginning of the Christian era. The process is similar to that used today in the manufacture of crucible steel. Small pieces of native iron were mixed with finely chopped wood in small crucibles only a few inches high. These crucibles were made of a wet mixture of red earth and charcoal. The crucibles were then sealed with the same material and heated in a charcoal furnace until the iron was melted. When cooled, the resulting product consisted of steel ingots, which weighed less than one pound and had a very good quality for early steel.

There are numerous but unauthentic rumors of early processes of iron and steel manufacture, some of them insisting that coal was used for this purpose at a very early date. These assertions, however improbable, are entitled to more or less credence for there are other and more marvellous unexplained facts in early iron history. The methods which were used in forging the heavy iron beams used in Indian temples and the iron pillars of Delhi will probably always remain a mystery. It is

also claimed by some historians that cast-iron was manufactured and used at early times. If the Greeks and Romans did know how to make and utilize cast-iron, their knowledge did not long survive, for there is no authentic mention of its use in Europe until about six centuries ago. The Japanese, Chinese, and people of India may have made use of iron in this form, but if they did they kept the art secret and used it but little.

We know very little regarding any developments of processes that occurred during the first seven centuries of the Christian era. The history of the industry during that period is very obscure, and with the possible exception of Spain, where the industrial arts were flourishing in a kingdom of the Visigoths, Europe was probably too engrossed with her political and religious struggles to indulge in either invention or scientific research.

At the beginning of the eighth century, the iron industry again revived and the old smelting furnace began a long period of development which did not cease until it evolved into the blast-furnace in the fourteenth century. In this early furnace, or bloomary, as it has been called, both steel and wrought-iron were produced. Both were contained in the same lump or bloom and were separated when possible by the workmen who cut up the bloom previous to its being forged into smaller ingots.

The transition from the bloomary to the blast-furnace was necessarily very gradual. It was necessary to increase the size of the furnace to use a blast; and since the early smelters were greatly annoyed by the cast-iron caused by the increased size of the bloomary, the output of iron was long restricted

by the inability of early iron workers to use cast-iron. This fact long retarded the use of the blast-furnace.

As soon as it was proved that cast-iron could be easily converted into malleable iron and also that iron castings were much more desirable and cheaper in many cases than forgings, the size of the old bloomarys was gradually increased until the blast-furnace naturally evolved. While all the Continental nations of Europe soon began using the blast-furnace, the Germans, Belgians, and French surpassed the others in its improvement. Their early experiments caused a very rapid increase in its use; besides, these nations soon acquired fame for their proficiency in metal working. At a very early date they were noted for the excellence of their castings.

The fifteenth and sixteenth centuries marked a great improvement in the art of iron manufacture, and the uses to which it could be put were thereby greatly enlarged. The blast-furnace was introduced into England early in the fifteenth century. From then on until the eighteenth century no marked changes were made in methods of manufacture. The old processes were gradually perfected,and water power was applied to furnish the blast and to run the forging hammers.

When coke came into use as a fuel the methods of refining iron changed only in detail. On the Continent where charcoal continued to be used, practically no developments occurred until as late as 1820, when the puddling-furnace was introduced into Sweeden. . At that time methods of forming iron into shapes which could be easily used were needed more than smelting improvements. Development in this line began in 1728 when John

Payne invented a process for rolling iron. This at once led to the manufacture of sheet-iron for tin-plate. Strange as it may seem there were no improvements made in rolling iron until 1783, when Henry Cort invented grooved rolls for rolling bars. It is a disputed fact whether the slitting mill preceded or followed Cort's grooved rolls. At any rate the use of slitting machines was not prevalent in English iron trade until after 1783, so the chronological precedence of the inventions is unimportant.

Up to 1740 there were three methods of steel manufacture in use. One was similar to the Catalan forge method of producing wrought-iron, giving what was known as natural or German steel. Another was the Indian method of converting small quantities of wrought-iron into steel by melting it with wood in small crucibles. The third has later been named the cementation process by which bar wrought-iron was made into steel by heating it in contact with charcoal, thus carbonizing it and producing blister-steel. All of these methods are still used in a more or less modified form.

With the exception of the growing use of mineral fuel, after Huntsman perfected the cementation process in 1740, there was little change in the methods of producing steel until the middle of the nineteenth century when the Bessemer process was invented. The principle of the so called Bessemer process was first discovered in 1851 by William Kelley, an iron manufacturer of Eddyville,Kentucky. The principle consists of the introduction of an air-blast into molten iron, thereby causing the carbon and phosphorus in the iron to unite with the oxygen of

the air and burn out.

About this same time Henry Bessemer of London conceived the same idea and experimented with it until in 1856 he was granted English letters of patent on his discovery. However, his first discovery proved valueless for the production of commercial steel, as his process removed all carbon from the iron and left oxygen in the resulting product. The process was perfected in England in 1858 when Robert Mushet obtained a patent for the recarbonization of steel by putting into the product of Bessemer's converter a triple compound of iron, carbon, and manganese, known as spiegeleisen.

In 1856 Bessemer applied for and obtained in the United States two patents for his invention. These were soon afterward set aside by the Commissioner of Patents when Kelly filed a claim of priority of invention. There has been much discussion regarding which of the two inventors deserves the most credit. While Kelly had discovered the principle at an earlier date than Bessemer, it has been well sustained that his discovery was accidental, regardless of his claims to the contrary. It is also well known that Kelly was not enterprising enough to sufficiently perfect his process that it might become commercially important. He manufactured his newly found product on a small scale, and it was not until the Bessemer process was much talked of in America that Kelly's invention became generally known. Nevertheless, he has the destinction of having constructed and used the first converter in America.

After the discovery of spiegeleisen by Robert Mushet, Bessemer soon evolved the Bessemer converter which produced steel at a rate which before that time was inconceivable. Steel manufacture at once became the leading industry of England. The profits on Bessemer's patents made him a fortune, and later the British Government conferred upon him the rank of knighthood in recognition of his efforts. Mushet never received his just due for making practical the use of Bessemer's invention. Bessemer gave him a small annuity, and later he was given a gold medal by the government.

In 1877 Sidney Thomas, a London chemist, invented a successful method for dephosphorizing iron by lining the converter with lime. His process has met with great favor in all European countries, expecially in Germany; but in the United States it has been used only to a limited extent.

The establishment of the Bessemer process has constituted a more important revolution in the steel industry than any preceding discovery or invention. It furnished precisely what had heretofore been needed, a cheap, rapid, and efficient method of manufacturing steel. However, it was many years after its invention before it attracted the attention it deserved, either in the United States or in the Continental countries.

In 1861 a company operating under the Kelly patents was organized in the United States. Bessemer had previously obtained United States patents on the machinery used in his process and Mushet had an American patent on the use of spiegeleisen. A company operating under the Bessemer and Mushet patents was organized at Troy, New York. However, neither company could

manufacture steel without infringing on patents owned by the other, and steel manufacture was at a standstill until 1866, when a combination of the two companies was effected and an arrangement was made which consolidated the three patents. Following this, the business of making Bessemer steel in America began to extend, and by 1876 thirteen companies were engaged in the industry.

The early development of the Bessemer steel industry in the United States was seriously handicapped by the lack of suitable pig-iron and converter lining. The scarcity of skilled workmen was another serious check. These difficulties have long since been overcome and now it is generally admitted that the Bessemer process has reached a higher state of perfection in America than in any other country.

The survival of the fittest was again forcibly demonstrated in the case of the Bessemer process. Later practice has proved that the open-hearth process of steel manufacture is more efficient in both cost and quality of the product. The recent rapid increase in the use of open-hearth furnaces makes it evident that the Bessemer converter is destined to become obsolete.

The open-hearth process of steel manufacture operates on the same chemical principles as the Bessemer process, i.e., the decarbonization and recarbonization of melted pig-iron. In the open-hearth process the pig-iron is melted or kept molten in a large dish-shaped vessel, or reverberatory furnace, by the heat of a regenerative gas-furnace. The decarbonization is effected by the addition of wrought-iron, steel scrap, or iron

ore, and the recarbonization by adding ferro-manganese or spiegeleisen.

Development in the use of the open-hearth process was long retarded by its one disadvantage - slow operation. Steel is manufactured by the process at a much lower rate of speed than the Bessemer method, but it has numerous advantages which for many purposes have caused it to supercede the Bessemer converter. Among these are: low first cost; greater uniformity of product; utilization of waste gases from the blast-furnaces; and greatest of all, utilization of waste and scrap steel. The new steel plant built at Gary, Indiana, by the United States Steel Corporation, is an evidence of the growing popularity of the open-hearth process. The steel corporation claims to make more steel in this city than Great Britain and Germany combined. In this plant there are eighty-four open-hearth furnaces and no Bessemer converters.

The open-hearth process is the result of a furnace invention that was made in 1856, the same year that Henry Bessemer obtained his most important patent. At that time Dr. Charles Siemens and his brother Frederick Siemens, both of German birth, but residents of London, perfected the regenerative gas-furnace. They intended to use it in the manufacture of all products requiring a high and uniform heat. In 1861 Dr. Siemens obtained a patent for the manufacture of steel in the reverberatory, or open-hearth furnace, which was a practical application of his earlier invention. All efforts to reduce this process to a suitable form for commercial use were unsuccessful until 1864 when Emile and Pierre Martin, French steel manufacturers, with the

assistance of Dr. Siemens, built a plant of reverberatory furnaces in France that were successfully operated.

An agreement between the Siemens-Martin interests resulted in the process being called the Martin-Siemens process on the continent, and the Siemens-Martin process in Great Britain. The latter name is generally used in the United States. Soon after the successful introduction of the new process in France Dr. Siemens built a plant at Birmingham, England. Today England uses both the Bessemer and open-hearth processes and in many plants a combination of the two processes.

The open-hearth process was not used in the United States for other than experimental purposes until 1868 when the New Jersey Steel and Iron Company built at Trenton, New Jersey, the first open-hearth furnace, which they successfully operated for the manufacture of steel. The method was gradually taken up by various companies until in 1890 there were sixty-two open-hearth plants in the United States. Until 1896 England was the greatest producer of open-hearth steel in the world, but since that time the United States has held the lead and doubtless will retain it for some time.

A new process has lately developed, which, although still in the experimental stage may ultimately supercede the open-hearth process. Electricity has invaded the steel industry just as it has so many other large productive interests. The electric-furnace has not yet been reduced to a sufficiently practical and economical form to compete with the open-hearth and Bessemer processes. It has recently been used in California where electric power is cheap; and has been much

experimented with by the United States Steel Corporation. The recent remarkable feats of cheap production of electrical power by the Commonwealth Edison Company of Chicago and several other large electric power companies may produce a revolution in the steel industry. The probability of this is, however, too uncertain to warrant a prediction, and is mentioned only as a possibility within the bounds of reason.

While the development of the processes used in the manufacture of raw steel are fundamental in the development of the steel industry, the various inventions which made steel a utility for so many different purposes played a very important part and one which deserves more than mere mention. This part of the history of steel began when Payne and Hanbury succeeded in rolling sheet-iron. Soon afterward, Smeaton invented cast-iron blowing cylinders and Cort developed grooved rolls. These inventions, together with the improved methods of foundry practice, made possible Watts' steam engine and Stephenson's locomotive. In 1825 England built the first railroad in the world and this furnished to the steel industry its greatest source of demand; for the railroad has proved the greatest of all consumers of steel. The invention of the steam hammer by Neilson, a Scotchman, was the last important improvement that Great Britain added to this part of the history of steel.

During the nineteenth century, the methods of steel production and use have so far developed that it is now molded, cut, forged, pressed, or built into any shape desired. The problems of the utility of steel are now economical instead of mechanical. The United States has become more proficient

in the production and use of steel than any other country. While this is partly due to our seemingly inexhaustible natural resources for iron production, the chief reason for our superiority is our ability to improve on and develop the invaluable engineering and metallurgical inventions of our English and German ancestors.

Recent developments in the science of metallurgy have greatly increased the utility of steel. An early investigator found that the addition of a small quantity of nickel to steel greatly increased its ability to withstand abrasion. This discovery has caused a long series of experiments. It has become an established fact that by making a very small change in the chemical composition of steel its physical properities can be greatly altered. For some time after this important principle was discovered no use was made of it, as it seemed impossible to find suitable alloys. At present, however, we have nickel, manganese, tungsten, vanadium, chrome, and various other steels, each having distinct qualities which make it especially adapted to some particular use.

History and Development of the Use of Steel in Transportation.

In no way has steel so aided the advance of civilization as it has by its application to the production and distribution of power. This one application of steel has produced all of our modern methods of transportation, all the machinery for our present manufacturing plants, and much of the agricultural equipment of the present time. Without the ~~aid of the~~ development in transportation, manufactures, and agriculture, the advance of civilization would have been exceedingly slow.

The railway and steel industries have probably aided each

other more than any other two commercial interests. Without steel the present excellence of railway traffic would have been impossible, and in return the railways now consume more than one-half of the annual output of steel. The development in the use of steel in railway construction and equipment has been most rapid since the invention of the Bessemer process. Before that time the high price of the metal had enforced the use of iron for rails and other railway equipment where a metal was necessary. However, its lack of durability made it far from an economical material, and thus railway construction was long retarded by the lack of a suitable metal.

The first Bessemer steel rail rolled in the United States was made in 1855 at the Cambria Iron Works, Johnstown, Pennsylvania. The manufacture of steel rails did not become prominent in the steel industry until about 1867. Since that time it has become one of the largest factors in the steel business. The strength, cheapness, and long life of steel rails has caused their use to become universal.

The first railway cars were built of wood, with the exception of the wheels and axles. In the last half century the increasing scarcity of timber and its consequent rise in price has caused engineers to replace it, wherever possible, with other materials. For this reason the wooden beams in the early cars were first replaced with steel and later a steel frame was used. It was found that the use of steel reduced the weight of the car and at the same time increased its strength. The increase in strength obtained by using an all-steel car was evident, as it had the decided advantage of being almost indestructible.

Although steel cars had been advocated for some time it was not until the beginning of the twentieth century that they came into general use. In 1906 the Pennsylvania Railway Company announced that all of their future cars would be of steel construction, the design of which would render them indestructible in either collision or fire. They alone in 1908 had a total of 324 all-steel cars in use. At that time the Pullman Company had 500 steel sleepers and diners in actual operation. With the exception of the flat type, steel freight cars have not yet come into common use, but it seems almost inevitable that these too will be replaced by steel cars.

The use of steel cross-ties has all the indications of becoming an important factor in increasing the use of steel for railway equipment. In many foreign countries where the cost of wooden ties is higher than that of steel, they have been used successfully and economically. It has been within the past few years only, that railways in the United States have found a use for steel ties. The growing scarcity of timber, its increased cost, it short life, and the resulting inconvenience caused by frequent road-bed repairs have caused a number of railroads to lay experimental stretches of road-bed with steel ties. The results of these experiments have consistently shown that the steel cross-tie is an innovation in railway road-bed construction which deserves more consideration than it has yet received. Those advantages of the steel tie which will eventually cause it to supercede wood - just as steel rails have superceded wooden rails - are: longer life; reduced wear on rails and rolling stock; reduction of

renewals; and uniform life regardless of the quality of the ballast or climatic conditions. All the above advantages combine to give steel a very decided ultimate economy.

The use of steel is as indespensible in all other parts of railway equipment as it is in the rolling stock and road-bed. The shops, the metal structures, and the bridges, the signal and interlocking switch systems are all the result of the adaptibility of steel to many uses. Without it our extensive railway systems of today could never have been perfected, and modern traffic would be confronted with the same problems that were solved a half-century ago.

When Robert Fulton first applied the steam engine to navigation, he opened a new era in the world's commercial history. While the first iron steamboats were built, about 1831, it was a long time before this branch of American industry began to flourish. From 1831 to 1865 several iron ships were built, but they were considered as experiments. However, during the civil war the appearance and performance of the Monitor created a demand for an ironclad navy. Under the impetus of the assistance and encouragement of the government the business of iron shipbuilding has revolutionized both commerce and war. All modern countries now have a steel navy; their commerce is carried on in steel ships; and their wharves are equipped with steel mechanisms for loading and unloading vessels.

The effect of steel on modern transportation has made possible the existence of the large cities of today. The United States has made a more rapid advance in methods of urban transit than any other country. Our street and

elevated railways are more cheaply and satisfactorily constructed and operated than those of any foreign country; and our achievements in subway traffic have attracted the attention of the whole world. Our marvelous utilization of steel in electrical construction has caused our superiority in city transit.

The automobile has been the most recent method of transportation calling for the use of steel. While so far it has been used more as a means of pleasure than an industrial improvement, the rapid increase in motor-truck manufacture proves that it will soon be put to practical use. The use of the new varieties of steel have greatly aided automobile construction, for the mechanical parts are subjected to greater vibrations that other forms of mechanism experience.

Recent experiments in aerial navigation have demonstrated that this branch of transportation may have an important future. The importance of steel in both this and other transit development in the past makes evident the fact that steel will be an important factor in the construction of future aerial crafts.

History and Development of the Use of Steel in Structural Engineering.

The application of steel to engineering construction has caused the existence of a new profession - structural engineering. The recently developed use of steel in bridge building and other forms of metal construction have made the structural engineer a necessity. While iron had long been used for columns and beams in building construction and had been found indespensible in bridge building, metal construction did not begin its real development until Bessemer made cheap steel a possibility.

Before the advent of the use of steel in structural work,

a five story building was considered about the limit of height, for the weight of the building was supported by brick and stone walls and pilasters. The lack of a strong and light material long retarded the construction of higher structures. Our modern cities are proof of what steel has done in revolutionizing architecture. City buildings in the downtown districts now range from five to forty stories in height. The climax in high building construction seems to have been reached in 1908 when the four highest buildings in the world were built. These were the Metropolitan Life Insurance Tower, the Singer Building, The City Investment Building, and the Church Street Terminal Building, all in New York City.

One of the chief advantages of steel in building construction is the fact that all the weight of the walls and floors can be carried by the steel skeleton frame. This permits a minimum amount of masonry. It also greatly reduces the weight of the structure and permits a better utilization of the available foundation area. The steel skeleton construction also permits of improved lighting facilities, as the breaking of the outside walls for window space merely reduces the weight instead of the strength, as it did in the old form of construction. Besides removing the danger of collapse from modern structures, steel has assisted in making them fireproof and has thus aided in lessening the greatest danger of city life.

The United States is renowned throughout the civilized world for her superiority in bridge building. Since steel was first applied to structural work the United States has

constantly been furnishing the entire world with new types of bridge construction. Probably one reason for our superiority in bridge engineering is the fact that, in this country, we have competition of design, a thing unknown in Europe. Again, our many wide rivers have made necessary the use of long spans and have forced our engineers to devote an unusual amount of time and study to these problems. Whatever the reason may be, the fact remains that our applications of steel in bridge building have not only astonished all other nations, but have furnished our home industry with a large source of consumption; for we not only manufacture all the steel for our own bridges, but export a considerable amount of bridge steel.

History and Development of the use of Steel in Agriculture.

The steel industry has caused a development in agriculture which is not fully realized by those who have received the most benefit therefrom. The cause of this is that the transition from the ancient iron-bound or tipped hand implements to the modern motor-driven steel mechanisms which plant, tend, and harvest our crops has been too gradual to be noticeable. America's great agricultural resources and advantages have caused us to do more in the way of late improvements than any other country.

Cyrus Mc Cormick has done much in the interest of modern agriculture, as he perfected the modern mower and self-binder. John Deere, the inventor of the steel plow, also deserves mention. In late years agriculture has come to be frequently spoken of as a profession. Mechanical improvement and scientific experiment have so developed it that a specialized education is now a necessity to the successful agriculturist.

Effect of the Development of the Steel Industry on civilization.

The use of steel in our modern life and its effect on the development of civilization are so varied and great that volumes could be written on the subject. It has been a very noticeable fact that in the world's history, since the beginning of the Christian era, the nation that has led in the production and consumption of iron and steel has during that time also held first rank in the development and extension of civilization. For this reason we are infinitely proud of the position of the United States in the steel industry.

Effect of the Steel Industry on the commercial and political advance of the United States.

We do not have the natural and political advantages for producing steel as cheaply as our European competitors. American labor is much more expensive and our ore and fuel supplies inconveniently located with respect to manufacturing centers. However, our ingenuity in practical things has enabled us to excel in the economical production of steel, notwithstanding these handicaps. The ability of the American engineer has perfected the steel and subsidiary industries to an extent which enables us to compete with foreign metal manufacturers in their own countries. Our open-hearth practice is the best in the world. Our proficiency in the manufacture of Bessemer and open-hearth steel surpasses that of any other nation. In the production of crucible steel our methods equal thoseof any other country in quality and efficiency. Our rolling mill practice has caused foreign manufactures to pattern after our methods. In the manufacture of the finest of cutlery steel, only, are we behind any nation, and the reasons for this are not mechanical, but commercial.

It is not just that we give to the inventive genius of the

American engineer the entire credit for our enviable position in the steel industry. The cool-headed, shrewd business man, whose executive and administration talents, whose foresight and wonderful ability for combining and organizing the many varied factors of so large an industry into an efficient productive unit, deserves more commendation than we realize.

Our progressive and creative spirit has caused our steel interests to combine their capital and consolidate under one management. The efficient management thereby obtained has concentrated the manufactures in districts or centers best located for economical production. Andrew Carnegie was the pioneer of American steel organization. The result of his efforts is evident in the present United States Steel Corporation.

The future of the steel industry need give us little worry. The United States alone has natural resources of ore and fuel that could supply the world for a long period. Though the sources of ore supply in the United States have changed from one locality to another several times, this is no indication that our supply is near exhaustion. Instead it is proof of the discovery of better qualities of ore. The main supply of ore was for a long time taken from Pennsylvania and Missouri. At present the largest portion is taken from Minnesota and Alabama.

The almost incredible change of the iron and steel industry during the past half-century is prophetic of wonderful advances in the near future. Developments in the past have conclusively proved the truth of a statement recorded in the second chapter of Daniel which says "Iron breaketh in pieces

and subdueth all things." To this metal we owe an inestimable debt of gratitude; for it has made possible our modern civilization; it has given the Caucasian race predominance over all other races; and it has placed the United States among the leading national powers of the world.

Table of References.

Steel and its History.	Jeans, J. S.
Railway Track and Trackwork.	Tratman, E. E. R.
Scientific American.	Volumes 1905, 1907, 1909 & 1910.
Engineering Digest.	Volume 1908.
Hill's Encyclopedia.	
Iron Age.	Volume 1908.
Steel, its History and Uses.	Swenk.
Encyclopedia Britanica.	
Manufacture and Properties of Structural Steel.	Campbell.
Iron and Steel.	Mushet.
Bessemer Steel.	Fitch.
Steel and Iron.	Greenwood.
American Engineering Competition.	The Times, London.
Cyclopedia of Construction, Volume 4.	Radford.
Materials of construction.	Thurston.
Basic Bessemer Process.	Wedding.
Iron and Steel.	Vosmaer.
Manufacture of Iron.	Overman.
Romance of Steel.	Casson.